Inventory Methods for Mountain Beaver, Bushy-tailed Woodrat & Porcupine

Standards for Components of British Columbia's Biodiversity No. 27

Prepared by
Ministry of Environment, Lands and Parks
Resources Inventory Branch
for the Terrestrial Ecosystems Task Force
Resources Inventory Committee

October 6, 1998

Version 2.0

Published by the
Resources Inventory Committee

Canadian Cataloguing in Publication Data

Main entry under title:

Inventory methods for mountain beaver, bushy-tailed woodrat and porcupine [computer file]

(Standards for components of British Columbia's biodiversity ; no. 27)

Available through the Internet.

Issued also in printed format on demand.

Includes bibliographical references: p.

ISBN 0-7726-3684-2

1. Aplodontia - British Columbia - Inventories - Handbooks, manuals, etc. 2. Bushy-tailed woodrat - British Columbia - Inventories - Handbooks, manuals, etc. 3. Porcupines - British Columbia -Inventories - Handbooks, manuals, etc. 4. Rodent populations - British Columbia. 5. Ecological surveys - British Columbia - Handbooks, manuals, etc. I. British Columbia. Ministry of Environment, Lands and Parks. Resources Inventory Branch. II. Resources Inventory Committee (Canada). Terrestrial Ecosystems Task Force. III. Title. IV. Series.

QL73 7.R626I58 1998 333.95'935 C98-960274-5

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Preface

This manual presents standard methods for inventory of Mountain Beaver, Woodrat and Porcupine in British Columbia at three levels of inventory intensity: presence/not detected (possible), relative abundance, and absolute abundance. The manual was compiled by the Elements Working Group of the Terrestrial Ecosystems Task Force, under the auspices of the Resources Inventory Committee (RIC). The objectives of the working group are to develop inventory methods that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species component of biodiversity.

This manual is one of the Standards for Components of British Columbia's Biodiversity (CBCB) series which present standard protocols designed specifically for group of species with similar inventory requirements. The series includes an introductory manual (Species Inventory Fundamentals No. 1) which describes the history and objectives of RIC, and outlines the general process of conducting a wildlife inventory according to RIC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. The Species Inventory Fundamentals manual provides important background information and should be thoroughly reviewed before commencing with a RIC wildlife inventory. RIC standards are also available for animal capture and handling (No. 3), and radio-telemetry (No. 5). Field personnel should be thoroughly familiar with these standards before engaging in inventories which involve either of these activities.

Standard data forms are required for all RIC wildlife inventory. Survey-specific data forms accompany most manuals while general wildlife inventory forms are available in the Species Inventory Fundamentals No. 1 [Forms] (previously referred to as the Dataform Appendix). This is important to ensure compatibility with provincial data systems, as all information must eventually be included in the Species Inventory Datasystem (SPI). For more information about SPI and data forms, visit the Species Inventory Homepage at: http://www.env.gov.bc.ca/wld/spi/ric_manuals/

It is recognized that development of standard methods is necessarily an ongoing process. The CBCB manuals are expected to evolve and improve very quickly over their initial years of use. Field testing is a vital component of this process and feedback is essential. Comments and suggestions can be forwarded to the Elements Working Group by contacting:

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Acknowledgments

Funding of the Resources Inventory Committee work, including the preparation of this document, is provided by the Corporate Resource Inventory Initiative (CRII) and by Forest Renewal BC (FRBC). Preliminary work of the Resources Inventory Committee was funded by the Canada-British Columbia Partnership Agreement of Forest Resource Development FRDA II.

The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First Nations peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report "The Future of our Forests".

For further information about the Resources Inventory Committee and its various Task Forces, please contact:

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Terrestrial Ecosystems Task Force

All decisions regarding protocols and standards are the responsibility of the Resources Inventory Committee. Background information and protocols presented in this version are based on substantial contributions from Thomas P. Sullivan, Pontus M.F. Lindgren, and Todd N. Zimmerling with helpful review comments from Les Gyug, Maria Leung and John Boulanger.

The Components of British Columbia's Biodiversity series is currently edited by James Quayle with data form development by Leah Westereng.

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1. INTRODUCTION

This manual presents background information and standard inventory protocols for a group of three different rodents; mountain beaver (*Aplodontia rufa*), bushy-tailed woodrat (*Neotoma cinerea*), and porcupine (*Erethizon dorsatum*). Although these rodents occupy different ecological niches, they share a number of common traits that make them an appropriate group of animals to discuss collectively. For example, all three of these rodents can be found in an irregular distribution over the landscape. This heterogeneous distribution creates a unique situation for an investigator that may otherwise be more accustomed to investigating small mammals with a more homogeneous distribution, such as deer mice (*Peromyscus maniculatus*) or voles (*Microtus* spp.).

All three species in this group are also known to leave conspicuous physical sign within their home range. Mountain beavers excavate burrows which can be readily identified. Bushy-tailed woodrats construct stick houses which are conspicuous to human observers, and porcupines leave well defined trails in snow cover, which can be followed to a den site.

This manual will give direction on how to accommodate these animals irregular distribution during their inventory and will outline how various animal traits of each species can be used to aid the inventory process.

INVENTORY GROUP

1.1 Mountain Beaver *Aplodontia rufa* (Rafinesque 1817)

Standard taxonomic code: M-APRU

Order: Rodentia (Rodents**)**

Family: *Aplodontidae* (Mountain beaver)

Synonyms: *Aplodontia californica, A. chryseola, A. major*, or *A. olympica* (Nagorsen 1990).

Other common names: Sewellel (Banfield 1974; Whitaker 1988), mountain boomer, boomer, whistler, mountain rat (Borrecco and Anderson 1980 - as cited in Cafferata 1992), gehalis, ground bear, or giant mole (Carraway and Verts 1993).

Distribution within British Columbia

This rodent can be found within the Cascade Mountain range as far south as east-central California (Banfield 1974). Within British Columbia, however, it is restricted to the southwestern part of the province, east of Aldergrove, west of Merrit, and south of the Fraser River (Cowan and Guiguet 1973).

Ecoregions: The mountain beaver can be found within the Lower Mainland, Pacific and Cascade Ranges, Thompson-Okanagan Plateaus, and Okanagan Range ecoregions (adapted from Cowan and Guiget 1973 and Demarchi 1988).

Biogeoclimatic zones: Mountain beavers can be found within the Coastal Western Hemlock, Mountain Hemlock, and Engelmann Spruce-Subalpine Fir biogeoclimatic zones (Adapted from Cowan and Guiguet 1973 and B.C. Ministry of Forests 1988).

Status

Harper *et al.* (1994) reports the subspecies *A. r. rufa* as a provincially red-listed species (*i.e*. candidate for legal designation as an endangered or threatened species) and the subspecies *A. r. rainieri* as a provincially blue-listed species (*i.e*. considered to be vulnerable or sensitive).

Habitat requirements

The mountain beaver's habitat requirements are largely governed by its unusually high demand for water. The primitive physiology of the mountain beaver's kidney is such that this animal is unable to efficiently concentrate the nitrogenous wastes (uric acid) produced within its body (Cafferata 1992; Carraway and Verts 1993). Consequently, wastes are expelled via relatively large quantities of water (*i.e.* dilute urine) when compared to more advanced animals that are able to concentrate and expel their wastes within smaller volumes of urine. This lack of water conservation requires that the mountain beaver have access to an abundance of water; either in the form of standing water, succulent vegetation, or both (Carraway and Verts 1993). As a result, mountain beavers are typically found in draws and moist areas on north to east slopes (Cowan and Guiguet 1973; Cafferata 1992), although south-facing slopes may also be inhabited (Carraway and Verts 1993), provided that the habitat is sufficiently moist. In fact, selection for wet, often riparian habitats is, in part, the reason for the artificial reference to the beaver (*Castor canadensis*) in the mountain beaver’s common name.

Due to its sensitivity to temperature, the mountain beaver also requires ground that is suited for its networks of burrows, where it may be buffered from inclement weather (Johnson 1971 - as cited in Cafferata 1992; Banfield 1974). Finally, the mountain beaver requires foraging habitats characterized by well-developed herb and/or shrub layers (see "Food Habits" below). Therefore, environments, such as a closed canopy forest, do not provide a suitable habitat for the mountain beaver. Neal and Borrecco (1981) note that mountain beavers are often associated with treeless openings found within closed canopy forests.

Food habits

Mountain beavers are generalist herbivores with a diet reported to consist of nearly all of the plant species found within their habitat (Voth 1968; Cowan and Guiguet 1973). More specifically, this rodent feeds on pteridophytes (ferns), grasses, forbs, hardwoods, mosses, shrubs, and, to the frustration of many foresters, conifers (Banfield 1974; Cafferata 1992; Sullivan 1992). The mountain beaver is unique in its ability to survive on a diet consisting entirely of sword fern (*Polystichum munitum*) and bracken fern (*Ptritium aquilinum*) (Cafferata 1992). Like pikas (*Ochotona* spp.), mountain beavers also dry small piles of vegetation in the sun near burrow entrances. The cured food is stored within an underground feeding chamber for consumption during the winter months when other food sources are scarce. Mountain beavers have also been observed to be coprophagic (Banfield 1974).

Daily activity and movement patterns

Mountain beavers alternate active and rest periods throughout the full twenty-four-hour day (Banfield 1974; Cafferata 1992) and as such cannot be correctly described as diurnal or nocturnal. However, these animals are often considered to be nocturnal because their night-time active periods last about 50% longer than during the day (average length of active period = 90 minutes) (Ingles 1959; Banfield 1974). Ingles (1959) noted that the largest activity peaks occur at 10:00 p.m. and at 3:00 a.m.

Food is rarely consumed above ground, rather it is dragged underground for safe consumption or storage. Although this rodent will usually only travel about 25 m from its underground nest chamber in search of food, distances of up to 110 m have been traveled by males during breeding season (Martin 1971).

Although this species is not gregarious, suitable habitats may be occupied by several individuals. Some co-use of runways has been reported, however, mountain beaver are generally territorial animals that will actively defend their space from conspecifics (Cafferata 1992).

Seasonal activities and movement patterns

During the winter season, mountain beavers do not hibernate. Instead they remain active below the snow surface in the subnivian space. Individuals may also tunnel to the snow surface and travel on top of it in search of food (Cafferata 1992).

Mountain beavers remain residents of their burrow network for more than three years (Martin 1971) of their estimated five to six year life span (Feldhamer and Rochelle 1982; Carraway and Verts 1993).

In general, females are not sexually mature until the year after birth (Pfeiffer 1958; Carraway and Verts 1993). Once mature, females give birth to a single litter of two or three young in late March or early April, after a gestation period of 30 days (Pfeiffer 1958; Banfield 1974; Cafferata 1992; Carraway and Verts 1993).

Physical sign

Feeding damage on conifer and hardwood plants (Lawrence *et al.* 1961; Harestad *et al.* 1986; Harestad 1982; Neal and Borrecco 1981; Cafferata 1992; Black 1994).

<u>Above-ground feeding damage</u>

Clipping of seedlings or branches - The appearance of this damage is typical of all rodent and lagomorph clippings; an oblique cut through the stem. Although very similar in appearance to feeding damage caused by cottontails (*Sylvilagus* spp.) and hares (*Lepus* spp.), mountain beaver clipping can be distinguished with the aid of some additional environmental clues. For example, cottontails and hares rarely clip stems of more than 0.75 cm in diameter, whereas mountain beavers can clip stems that are up to 2.5 cm in diameter. In addition, areas that have been damaged by cottontails or hares will frequently have the readily recognized "rabbit pellets" scattered around the base of the damaged plants. Mountain beavers, on the other hand, never expel their feces above ground.

Mountain beavers are well adapted to climbing and so do not only feed on plants near ground level, but also in trees. This rodent can also cause damage to lateral and terminal shoots high in the trees. Lateral branch clippings can be recognized as having been caused by mountain beavers if 2.5 to 7.5 cm stubs are left attached to the main stem.

Basal barking - The removal of bark near the base of trees (usually with diameters from 10 to 15 cm at ground level) may indicate the presence of a mountain beaver. The bark is pulled off in strips leaving horizontal and diagonal tooth marks and irregular claw marks scattered on the exposed surface of the tree. The mountain beaver does not leave any strips of bark on the ground, but rather it packs them away underground. This damage should not be confused with the basal barking produced by bears (*Ursus* spp.), as bear damage is readily identified by the large strips of bark left at the base of the tree and the deep, vertical grooves caused by the scraping of vascular tissues by the bear's canine teeth.

<u>Below-ground feeding damage</u>

Barking and undermining of roots - Because of their burrowing habits, mountain beavers can also damage plants below ground. During the barking of a tree's roots, the mountain beaver also undermines the tree (*i.e*. removes the dirt from around the roots). This damage can be observed directly (exposed roots with tunneling throughout the root mass), but will also be reflected in the resulting instability of local trees or saplings, patches of which may be blown or pushed over due to an apparent lack of root support.

Further confirmation that observed feeding damage has been caused by a mountain beaver can be made if the damage is patchy in distribution, creating small clearings that surround a well developed burrow system (see "Burrows" for more details).

Burrows (Lawrence *et al.* 1961; Cowan and Guiguet 1973; Banfield 1974; Harestad *et al.* 1986; Cafferata 1992; Black 1994)

The burrows used by mountain beavers are useful signs for presence/not detected inventories as they are often quite conspicuous, although some may be concealed by a dense understory, natural debris, and/or logging slash. The burrows are large in diameter (15 cm) and therefore will sometimes cave in, leaving ditch-like depressions here and there throughout the burrowing habitat. Several entrances may be observed with large, fan shaped piles of excavated dirt scattered about the entrance hole.

The entrance to a mountain beaver burrow can easily be distinguished from that of a mole (*Neurotrichus* and *Scapanus* spp.) by 1) the size; a mountain beaver's entrance is much larger than a mole's and 2) a mole's entrance is always plugged with dirt, whereas a mountain beaver's entrance is not. Entrances to mountain beaver burrows are also often littered with clipped vegetation.

An additional observation that can confirm the inhabitant of a burrow system as a mountain beaver are the tracks which may be found in the soft, excavated dirt that surrounds the entrances to the burrows. Mountain beaver tracks are depicted on page 27 in Harestad *et al.* (1986).

Bushy-tailed Woodrat — *Neotoma cinerea* (Ord 1815)

Standard taxonomic code: M-NECI

Order: Rodentia (Rodents)

Family: Muridae (Murids)

Subfamily: Sigmodontinae (New World Rats and Mice)

Synonyms: *Mus cinereus*, *Myoxus drumondii*, *Neotoma occidentalis*, or *N. saxamans* (Nagorsen 1990).

Other common names: Pack rat (Banfield 1974; Nagorsen 1990) or mountain pack rat (Whitaker 1988).

Distribution within British Columbia

Most literature reports that the bushy-tailed woodrat is found throughout all of British Columbia's mainland and is absent from the coastal islands (Cowan and Guiguet 1973; Harestad 1982; Stevens and Lofts 1988; Nagorsen 1990). Some authors, however, report that this rodent is also absent from the northeast and northwest corners of the province (Escherich 1981; Whitaker 1988).

<u>Ecoregions</u>: The bushy-tailed woodrat can be found in every mainland ecoregion of the province (adapted from Cowan and Guiguet 1973 and Demarchi 1988).

<u>Biogeoclimatic zones</u>: The bushy-tailed woodrat can be found in all 14 of the biogeoclimatic zones of British Columbia (adapted from Cowan and Guiguet 1973 and B.C. Ministry of

Forests 1988). Meidinger and Pojar (1991) consider the bushy-tailed woodrat to be a "representative species" in the Coastal Western Hemlock biogeoclimatic zone.

Status

The bushy-tailed woodrat is not listed as either a blue or a red listed species (Harper *et al.* 1994). The bushy-tailed woodrat is on the provincial yellow list. This rodent is not considered to be in jeopardy and is, therefore, not protected (Stevens and Lofts 1988).

Habitat requirements

The bushy-tailed woodrat requires habitat that offers good security cover. Sullivan (1992) reports that woodrat activity is significantly higher in areas that have 75 to 100% cover than in areas with less cover. The cover provided within rocky habitats such as talus slopes, caves, cliffs, river canyons, and rock outcrops in open forests appear to be favorite habitats for this woodrat (Banfield 1974; Clark 1975; Escherich 1981; Harestad 1982; Carey 1991). In the absence of rocky habitat, security cover can be provided by logging slash (Carey 1991), hollow logs, abandoned buildings, and mine shafts (Cowan and Guiguet 1973; Banfield 1974).

Woodrat habitats provide woodrats with a suitable sites for building their stick “houses”. Woodrats owe their other common name of *pack rat* to their association with stick houses, which are generally quite large (1 to 1.8 m in height) and built out of woody debris, dried vegetation, and other objects the woodrat can collect, including human artifacts such as silverware, jewelry and clothing (Banfield 1974; Escherich 1981; Salmon 1983; Carey 1991). These houses are preferably situated within the shelter of a rocky overhang, but can sometimes be found in the open or even up a tree (Escherich 1981). Escherich (1981) notes that suitable habitat for house building is the primary resource limiting the distribution of the woodrat.

Although they are often referred to as houses, the piles of debris created by woodrats do not often function as shelters and woodrats do not usually reside therein. Large woodrat piles function more as a storage dump than a house (Cowan and Guiguet 1973). Their true nests are small (about 15 cm in diameter), cup shaped, and are made up of finely shredded bark and other soft materials such as fur (Escherich 1981; Harestad 1982; Carey 1991). These nests may be found within the larger stick house, but are more commonly found in a sheltered spot nearby (Banfield 1974; Escherich 1981; Carey 1991).

Food habits

The woodrat is an omnivorous rodent that will make a meal out of a variety of plants, insects, small amphibians, and carrion (Cowan and Guiguet 1973; Banfield 1974; Escherich 1981). The majority of the woodrat's diet is comprised of green and dry vegetation. Preference is shown for the foliage of herbs, shrubs, and trees, but not grasses (Banfield 1974). Carey (1991) reports that this woodrat also feeds on the vascular tissues of Douglas-fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sichensis*), and western hemlock (*Tsuga heterophylla*). Willow (*Salix* spp.) leaves are also a favoured food of the woodrat (Harestad 1982). Bushy-tailed woodrats stockpile large quantities of dried vegetation to sustain them throughout the winter months (Banfield 1974; Escherich 1981).

Daily activity and movement patterns

The bushy-tailed woodrat is nocturnal in activity, but, can be observed occasionally during the day. Banfield (1974) reports that this woodrat is quite sedentary, and will rarely venture far from its nest. It is most active during the half hour after sunset and dawn (Banfield 1974). Although the bushy-tailed woodrat can climb trees, and will occasionally locate its stick house up a tree, it is less arboreal than its semi-arboreal cousin, the dusky-footed woodrat (*Neotoma fuscipes*) (Escherich 1981; Harestad 1982; Sullivan 1992).

Bushy-tailed woodrats are a solitary species that defend territories (Banfield 1974). Males spend considerable time marking their territory with their ventral musk glands, which they rub on toilet posts, food caches, and nests (Banfield 1974; Escherich 1981).

Seasonal activities and movement patterns

The bushy-tailed woodrat does not hibernate, instead it actively prepares for the winter by stockpiling a cache of vegetation, which it gathers and dries in the sun during the growing season (Cowan and Guiguet 1973; Harestad 1982). Winter months are primarily spent below the snow among the cover provided by their rocky habitat, however, short trips may be made over the snow's surface (Banfield 1974).

Woodrats remain solitary, except during the breeding season (Banfield 1974), which in British Columbia begins in late March and lasts until late May. After a gestation period of 27 to 32 days (Egoscue 1962), females give birth to an average of four young (range of one to six) during early May to late June (Cowan and Guiguet 1973; Harestad 1982; Carey 1991). Several authors report that the bushy-tailed woodrat has multiple litters per year (Egoscue 1962; Banfield 1974; Escherich 1981). However, within British Columbia, the woodrat is commonly reported as having only a single litter per year (Cowan and Guiguet 1973; Harestad 1982; Carey 1991).

Bushy-tailed woodrats do not travel significant distances throughout the year (with perhaps the exception of dispersing juveniles), remaining in the near vicinity of their stick houses and nesting sites.

Physical Sign

Urine and fecal deposits (Cowan and Guiguet 1973; Escherich 1981; Harestad *et al.* 1986)

Good indicators of bushy-tailed woodrat presence are the deposits of urine and feces that accumulate within this animal's home range. Feces and urine can form a thick tar-like substance (often mistaken for some kind of mineral), if deposited in a spot sheltered from the rain, such as within a cave or under a rock overhang. Bright white streaks result from urine deposited on rocks not sheltered from the rain. The rain is thought to leach out the organic components of the urine leaving a white calcareous deposit behind. These white deposits are useful sign to look for when sampling for bushy-tailed woodrats, as they can be observed from a distance and are often indicative of occupation (or former occupation) of an area by a woodrat.

Because feces and urine deposits are very persistent, lasting for thousands of years in sheltered areas such as caves, and decades on exposed surfaces such as cliffs, care must be taken not to confuse past use of a site with that of current use. Simply locating fresh streaks of urine can quickly answer this question. Fresh urine can be recognized by its transparent yellow to opaque brown colour, skunky odour, and stickiness.

Stick houses (Cowan and Guiguet 1973; Banfield 1974; Escherich 1981; Harestad 1982; Carey 1991; Sullivan 1992)

Bushy-tailed woodrats are or have recently been present in a study area if an investigator discovers the large stick “houses” used by this woodrat. These structures, made primarily out of woody material and a variety of other debris, are often located in a sheltered area such as a cave, under a rock ledge, within an abandoned building, around the base of a tree or log, inside a hollow snag, or sometimes even up a tree. Although woodrat “houses” are usually not placed in the open, because of their large size (0.9 to 1.8 m), they can usually be spotted with relative ease.

Damage caused by feeding and construction (Banfield 1974; Harestad *et al.* 1986; Carey 1991; Sullivan 1992; Black 1994)

Because the bushy-tailed woodrat is an animal that feeds on a large variety of plants within its home range, clipped shoots and branches, with the usual oblique cut common to most rodent feeding scars, are possible indicators of woodrat presence. However, such feeding sign is difficult to distinguish from other rodent feeding damage. A less ambiguous sign produced by this woodrat, are the patches of bark removed from the boles of trees for nest construction. From a distance, this debarking may be confused with that of the porcupine (*Erethizon dorsatum*) or tree squirrels (*Tamiasciurus* spp.); however, woodrat damage differs from these other animals’ damage in several ways. Unlike the tree squirrels that discard the bark and feed on the exposed sapwood, the bushy-tailed woodrat transports all of the removed bark to its nest for construction. Therefore, there will be no discarded strips of bark found beneath the trees damaged by bushy-tailed woodrats, as there would beneath trees damaged by tree squirrels or porcupines. In addition, woodrats do not feed on the sapwood, rather they just remove the outer bark (often the sapwood is not even exposed), whereas, porcupine and tree squirrel feeding will always expose the sapwood.

Porcupine *Erethizon dorsatum* (Linnaeus 1758)

Standard taxonomic code: M-ERDO

Order: Rodentia (Rodents)

Family: Erethizontidae (New World Porcupines)

Synonyms: *Erethizon epixanthus, E. epixanthus myops, E. epixanthus nigrescens* (Nagorsen 1990), or *Hystrix dorsata* (Woods 1973).

Other common names: American Porcupine (Banfield 1974), porky, or quill pig (Schemnitz 1983).

Distribution within British Columbia

Porcupines are found throughout the mainland and on some of the provinces coastal islands, from valley bottoms to the treeline (Stevens and Lofts 1988; Nagorsen 1990). The only large areas void of porcupines in the Province are Vancouver Island and the Queen Charlotte Islands (Banfield 1974). Harestad (1982) notes that porcupines are not common on the coast.

Ecoregions: The porcupine can be found in every mainland ecoregion of the province (adapted from Cowan and Guiguet 1973 and Demarchi 1988).

Biogeoclimatic zones: The porcupine can be found in all of British Columbia's 14 biogeoclimatic zones (adapted from Cowan and Guiguet 1973 and B.C. Ministry of Forests 1988). Meidinger and Pojar (1991) consider the porcupine to be a "representative species" in the Montane Spruce, Sub-Boreal Pine-Spruce, Sub- Boreal Spruce, Engelmann Spruce-Subalpine Fir, Boreal White and Black Spruce, and Spruce Willow Birch biogeoclimatic zones.

Status

The porcupine is not listed as either a blue or a red listed species (Harper *et al.* 1994). The porcupine is on the provincial yellow list. This rodent is not considered to be in jeopardy and is, therefore, not protected (Stevens and Lofts 1988).

Habitat requirements

Porcupines require habitat that has a well developed herb and shrub layer as it provides security from predators as well as an important source of food (Banfield 1974). Security cover can also be provided by logging slash (Schemnitz 1983). In addition to a good ground cover, the porcupine requires access to trees as they spend most of the daylight hours resting within the branches of a forest canopy (Banfield 1974; Smith 1982*a*; Schemnitz 1983; Dodge and Borrecco 1992). Trees are most important during the winter as they become the primary food source for porcupines (see "Food habits" below) (Clark 1975, Roze 1989). Winter climates often require that porcupines seek shelter within a winter den (Roze 1989). Preferred denning sites include caves, rock crevices, hollow logs, root wads, logging slash, culverts, or even next to the stem under the low growing branches of a conifer (Banfield 1974; Harestad 1982; Roze 1989).

Food habits

The porcupine is a herbivorous rodent that feeds on a variety of herbs and shrubs during the spring and summer months. During the growing season, their diet consists of grasses, forbs, aquatic succulents, and cultivated crops (Cowan and Guiguet 1973; Banfield 1974; Harder 1980; Dodge and Borrecco 1992). During the winter, when the ground vegetation is covered by a blanket of snow, the porcupine's food habits shift to an almost exclusive diet of hard and softwoods. The porcupine removes the outer bark of these trees and feeds on the vascular tissues (cambium and phloem) and to a lesser extent on the lateral tips of branches.

Sullivan and Cheng (1989) report that porcupines show a preference for vigorous dominant and co-dominant trees. This preference is likely due to the larger radial increment (*i.e*. greater abundance) of vascular tissues within these vigorous stems. During a study of porcupine feeding damage in north-coastal British Columbia, Sullivan *et al.* (1986) reported a preference for western hemlock (*Tsuga heterophylla*) and Sitka spruce (*Picea sitchensis*). Cowan and Guiguet (1973) note that, when available, ponderosa pine (*Pinus ponderosa*) is a favoured tree species. Other authors have noted several other species of pine as being selected, when available (lodgepole pine, *Pinus contorta*, Daniel and Barnes 1958; scotch pine, *Pinus sylvestris,* Rudolf 1949; limber pine, *Pinus flexilis,* Gill and Cordes 1972).

Like other herbivores, the porcupine is often deprived of certain minerals not readily present in their diet. As a result, porcupines will often consume bones or antlers in an attempt to provide their bodies with needed minerals (Banfield 1974). Salt (NaCl) is often sought after in the spring, as their sodium levels are often very low (Roze 1989). This salt drive may result in a porcupine eating anything that has a trace of salt in it, including footwear and tool handles that have had salty perspiration rubbed on during their use (Clark 1975; Harestad 1982; Roze 1989).

Schemnitz (1983) notes that porcupine feeding scars may be an important agent for creating snags, as the wounds left by feeding serve as an entrance way for decay fungi. Porcupine feeding within trees is also believed to be of benefit for ground-dwelling herbivores, such as the snowshoe hare (*Lepus americanus*), which consume the litter fall that results from feeding activities (Ferguson and Merriam 1978; Schemnitz 1983).

Daily activity and movement patterns

Porcupines are generally considered to be nocturnal. However, on occasion they can be observed foraging during the daylight hours, especially at dusk. Activity is most common during the dark hours, when most time is spent foraging for ground vegetation. Banfield (1974) reports that porcupines have been observed to travel an average of 110 m per night and only 80 m per day. During spring, summer, and early fall, porcupines generally spend the daylight hours resting within the high branches of a tall tree. Night time is then spent foraging for herbs and shrubs found on the forest floor.

During late fall and winter, time spent on the forest floor is sharply reduced and porcupines spend most of their time within a winter den or in the forest canopy; resting during the day and feeding on the tree's vascular tissues at night. Short trips may be made on the ground, from tree to tree or from a winter den to favoured feeding trees.

Porcupines are generally not very aggressive towards conspecifics and do not defend a territory (Woods 1973). However, Dodge (1967) reports that porcupines will defend their feeding trees (as cited in Woods 1973) and males will enter into combat for a female during breeding season (Roze 1989).

Seasonal activities and movement patterns

Porcupines are active year round and as such require a layer of body fat to supplement their diet throughout the harsh winter months. Fat reserves are acquired from early spring to late summer (Woods 1973). The porcupine's home range is significantly reduced during the winter months as its activity is generally restricted to an area 40 m to 100 m from a winter den (Speer and Dilworth 1978; Roze 1984; Griesemer *et al.* 1994). Roze (1989) reports that porcupines seek out a suitable winter den after an average of seven days of below freezing weather.

Females become sexually mature at about 18 months of age, and therefore, do not successfully breed until their second year. Males become sexually active (scrotal) during late August or September (Woods 1973) and breeding occurs soon after. The females are polyoestrus and will repeat ovulation (cycles of 25 to 30 days), if fertilization is not successful the first time (Woods 1973). After a relatively long gestation period (209 to 217 days) (Banfield 1974), the porcupine gives birth to a single young (twins are rare) in April, May, or June (Cowan and Guiguet 1973; Woods 1973).

The low reproductive potential of the porcupine is balanced by its high rate of survival (Harestad 1982; Schemnitz 1983) and relatively long lifespan (for a rodent). The young porcupine stays with its mother for five to six months, after which time the young disperse

(Clark 1975). Porcupines are estimated to live between four and ten years (Brander 1971; Banfield 1974; Harestad 1982; Dodge and Borrecco 1992). Although the porcupine is considered to be a solitary animal, small family groups have been observed to occasionally den together during the winter (Banfield 1974; Harestad 1982).

Other

The porcupine is the second largest rodent found in Canada (Banfield 1974), weighing between 4.5 and 12.7 kg (Harestad 1982). The only Canadian rodent that supersedes the porcupine in size is the beaver (*Castor canadensis*), which can reach weights of up to 35 kg (Banfield 1974).

Physical sign

Feeding damage (Cowan and Guiguet 1973; Banfield 1974; Harestad 1982; Harestad *et al.* 1986; Roze 1989; Dodge and Borrecco 1992; Black 1994)

The porcupine feeds on a variety of herbs and shrubs throughout the spring and early summer. It is the porcupine's habit of feeding on trees during the fall and winter, however, that provide an investigator with useful sign for sampling. Like several animals that feed on trees, the porcupine consumes small twigs and vascular tissues. This damage may result in a reduction in radial growth or mortality of the stem, directly due to the damage, or indirectly through insect or disease penetration into the sapwood (Curtis 1941; Storm and Halvorson 1967; Sullivan *et al.* 1986; MacHutchon 1990; Krebs 1994). Removal of bark can occur near the ground (basal barking), but, more commonly occurs high in the canopy. If the tree is girdled (vascular tissue removed from the entire circumference of the stem) by basal barking the tree will die. If, however, the main stem is girdled high within the canopy, the terminal above the point of damage will die, and a lateral branch will begin to turn upwards and become the new terminal shoot. Consequently, repeated porcupine feeding within the canopy of a tree will eventually lead to a deformed crown that appears crooked (few feeding injuries) or bushy (several feeding injuries).

Porcupine feeding on the vascular tissue of conifer trees is characterized by prominent, horizontal and diagonal incisor marks (2.5 mm in width) on exposed sapwood (Lawrence *et al.* 1961; Roze 1989). Bark “chips” at the base of a porcupine feed tree are readily identifiable. As porcupines do not consume the outer bark, this layer is discarded during feeding and pieces of outer bark can be found in a large radius around freshly damaged trees. Pieces of twigs discarded during feeding can also be found at the base of feed trees however, this feeding sign can often be hard to identify as porcupine or squirrel feeding. In addition, the base of favourite feeding trees can have an accumulation of droppings. Porcupine droppings are about 25 mm long, curved with rounded ends.

Tracks (Banfield 1974; Harestad 1982; Smith 1982*b*; Harestad *et al.* 1986; Roze 1989)

During winter months, when snow accumulations cover the ground, porcupines become relatively easy to track. Porcupines are relatively short animals with very stout legs. As a result, they are unable to lift their legs out of the snow for each step, and must push through the snow. In deep powder (>10 cm) a trough-like path is plowed through the snow by the porcupine's body. This path is scoured with side-to-side drag marks created by the quilled tail. In smaller accumulations of snow, porcupines produce very distinct foot pad marks, with prominent claw marks. Porcupine tracks are depicted on page 28 of Harestad *et al.* (1986). Without good snow cover (i.e. enough accumulation to cover the ground under trees), it is not recommended to attempt sampling porcupines based on tracks. Speer and Dilworth

(1978), found that porcupines tend to reduce the energetic cost of traveling through snow by using areas close to tree trunks or under over-hanging branches, where snow levels are lower.

PROTOCOLS

This section will discuss the recommended methods for sampling mountain beavers, bushy-tailed woodrats, and porcupines for each of the three levels of inventory, as outlined in Table 1. These methods are recommended on the basis of their effectiveness and their efficiency in terms of time and financial requirements, and were chosen after careful consideration of all available methods.

Table 1. Recommended methods for inventory of Mountain beaver, Bushy-tailed Woodrat, and Porcupine in British Columbia at three levels of intensity.

Species	Recommended Method		
	Presence/Not Detected	**Relative Abundance**	**Absolute Abundance**
Mountain Beaver	Physical Sign	Physical Sign (Active Nest Site Count)	Mark-release-recapture
Bushy-tailed Woodrat	Physical Sign	No methods recommended at this time	Mark-release-recapture
Porcupine	Physical Sign	Physical Sign (Active Den Counts)	Mark-release-recapture

1.2 Sampling Standards

The following standards are recommended to ensure comparison of data between surveys, and to mitigate several sources of bias common in surveys. Individual protocols provide more detailed standards applicable to the method(s) and design recommended.

1.2.1 Habitat Data Standards

A minimum amount of habitat data must be collected for each survey type. The type and amount of data collected will depend on the scale of the survey, the nature of the focal species, and the objectives of the inventory. As most provincially-funded wildlife inventory projects deal with terrestrially-based wildlife, the terrestrial Ecosystem Field Form developed jointly by MOF and MELP (1995) will be used. However, under certain circumstances, this may be inappropriate and other RIC-approved standards for ecosystem description may be used. For a generic but useful description of approaches to habitat data collection in association with wildlife inventory, consult the introductory manual, *Species Inventory Fundamentals* (*No. 1)*.

1.2.2 Survey Design Hierarchy

Mountain beaver, woodrat and porcupine surveys follow a sample design hierarchy which is structured similarly to all RIC standards for species inventory. Figure 1 clarifies certain terminology used within this manual (also found in the glossary), and illustrates the appropriate conceptual framework for a presence/not detected physical sign survey for a bushy-tailed woodrat survey. A survey set up following this design will lend itself well to standard methods and RIC data forms.

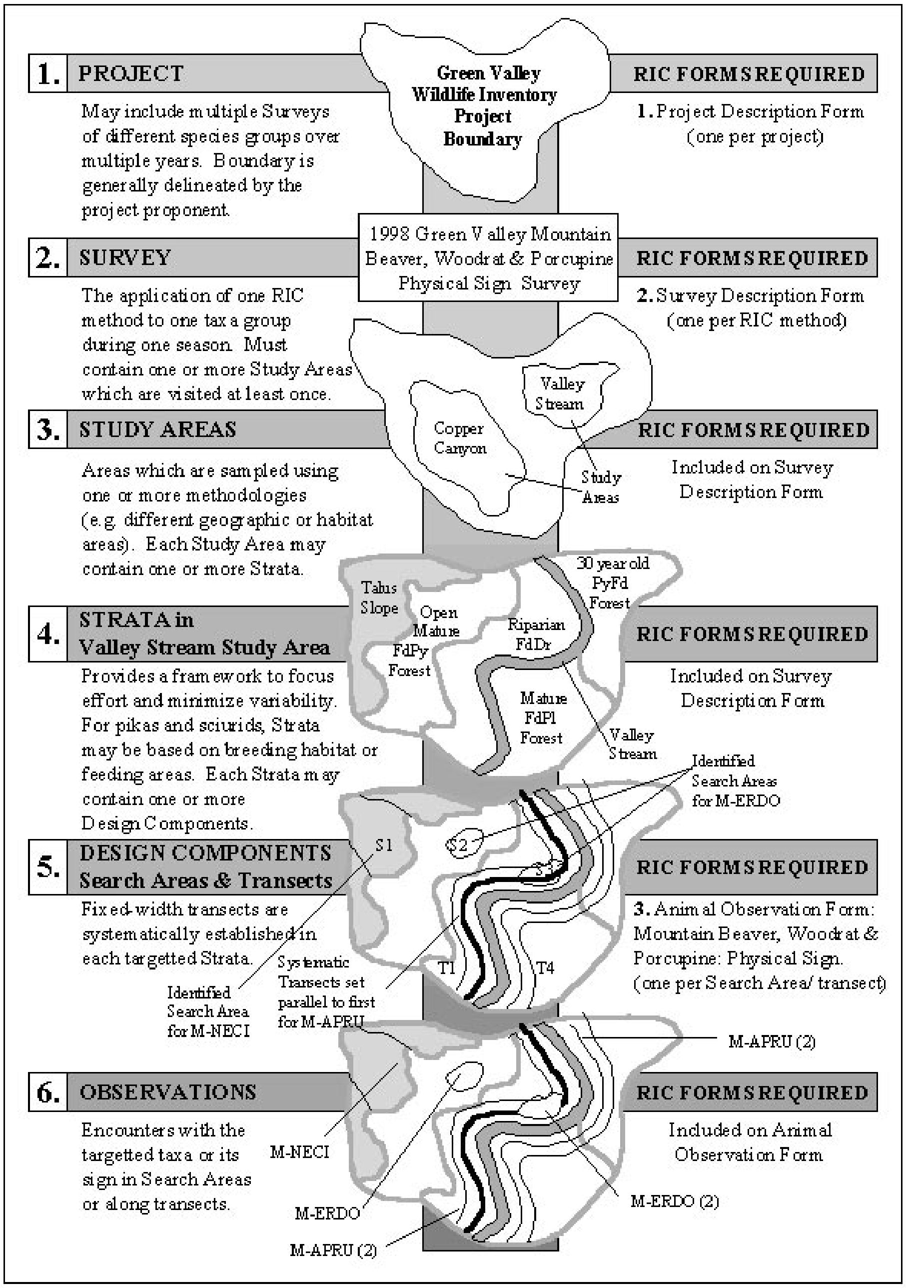

Figure 1. RIC species inventory survey design hierarchy with examples.

Inventory Surveys

The table below outlines the type of surveys that are used for inventorying mountain beaver, bushy-tailed woodrat, and porcupine for the various survey intensities. These survey methods have been recommended by wildlife biologists and approved by the Resources Inventory Committee.

Table 2. Types of inventory surveys, the data forms needed, and the level of intensity of the survey.

Survey Type	Forms Needed	*Intensity
Physical Sign	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - General • Animal Observation Form- Mountain Beaver, Bushy-tailed Woodrat, & Porcupine Physical Sign • Ecosystem Field Form	• PN • RA (for Mt. Beaver & Porcupine)
Mark-release / Recapture Mt. Beaver & Bushy-tailed Woodrat	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - General • Capture Form - Mountain Beaver & Bushy-tailed Woodrat • Animal Observation Form- Mountain Beaver & Bushy-tailed Woodrat Capture [For more detailed capture information, please use Animal Handling Form - Capture: Medium to Large Animals (Manual No. 5)] • Ecosystem Field Form	• AA
Mark-release / Recapture (MRR) Porcupine	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form - General • Animal Handling Form - Capture: Medium to Large Animals (Manual No. 5) • Animal Observation Form - Location by Radio-telemetry (Manual No. 5)	• AA
Any Survey Type	• Wildlife Inventory Survey Collection Label - is used whenever a voucher specimen is collected.	

* PN = presence/not detected (possible); RA = relative abundance; AA = absolute abundance

1.3 Presence/Not detected

Recommended method: Physical sign survey.

1.3.1 Physical Sign

The mountain beaver, bushy-tailed woodrat, and porcupine are particularly well suited for physical sign sampling because all three of these species leave conspicuous signs throughout their habitat. In addition, all of these animals have small home ranges (at least in winter in the case of porcupines), and therefore are likely to be found in the vicinity of their sign. Although all species have conspicuous sign, the methods recommended for surveying differs slightly between species and will be explained throughout the following section.

Office procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals* for information on sampling design, habitat description and reporting.
- Determine the Project Area and outline it on a small to large scale map (1:250,000 – 1:20,000).
- Obtain maps for project and Study Area(s) (*e.g.*, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps; 1:5000 air photos are generally best to evaluate habitat types).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps. Use this information to delineate potential Study Areas on maps.
- Delineate one to many Study Areas within this Project Area. Study Areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the sampling design then strata within the Study Areas should represent relevant strata in the larger Project Area.
- If necessary, stratify each Study Area based on expected density or habitat type (*e.g.* conifer forest, deciduous forest).

Sampling design

Mountain beavers

- Mountain beavers have a strong habitat association with wet and moist areas, as a result, a great deal of time and effort can be saved by beginning the presence/not detected survey in the most preferred habitat.
- Using air photos or an appropriate scale map, identify wet/moist areas within the Study Area.
- The highest quality habitats are generally along seepage areas and small streams that are not prone to flooding (L. Gyug pers. comm.; Beir 1989; Todd 1992). These should be identified as Search units (specific portions of the Study Area on which search effort was focused e.g. seepage areas).
- Establishing likely search routes along these features will provide the most efficient means of conducting a presence/not detected survey for mountain beaver.

- An overview helicopter flight may be beneficial in identifying likely Search units that do not show up on air photos or maps, owing to their small size or recent habitation.
- If this initial search does not produce sign of mountain beaver activity, then systematic transects can be established to ensure coverage of the entire Study Area (see section "Systematic transects").

Bushy-tailed woodrats

- Woodrats make extensive use of talus slopes, caves, cliffs, river canyons and rock outcrops in open forest. These features should be identified (using air photos and an appropriate map) as search units within the Study Area prior to commencing the survey.
- As with mountain beavers, the survey for bushy-tailed woodrats should initially concentrate on places within the Study Area which possess known preferred habitat characteristics. Initial search routes should target these habitat features.
- If this initial search does not produce sign of bushy-tailed woodrats, then systematic transects can be established to ensure coverage of the entire Study Area (see section "Systematic transects").

Porcupines

- Porcupines tend to damage trees in close proximity to their winter den sites (Speer and Dilworth 1978; Roze 1984; Griesemer *et al.* 1994) and as a result, damaged trees will appear in a clumped distribution across the landscape. These clumps of damaged trees can be readily identified from a distance, during a quick field reconnaissance. As the damage is usually in the top 1/3 of the tree, and freshly exposed sapwood is bright white in colour (fading to grey after several months to a year), identifying the damage is very simple.
- Field reconnaissance of the Study Area is most easily accomplished in more mountainous areas from viewpoints where the majority of tree tops can be seen. In flatter terrain, a helicopter flight may be necessary. Although this may require initial expense, identifying the location of these damage clumps, which will act as Search units, can ultimately save money by reducing the number of days crews spend walking through forest where porcupine sign is absent.
- Depending on the objective of the survey, the field reconnaissance may be enough to complete the survey, as this can quickly confirm the presence of porcupines if fresh feeding damage is observed.
- If the survey requires more information, then crews should begin their work at the identified damage clumps (Search units) where fresh feeding damage and porcupine tracks are most likely to be observed.
- If the field reconnaissance does not identify damage clumps in the Study Area, then systematic transects should be used (see the section "Systematic transects").

Systematic transects

- Length and number of transects are variables that will affect the accuracy of the results.
- It is recommended that several transect lines be located within the Study Area in a systematic pattern.
- Transects should be systematically placed to cover the entire Study Area with equal effort.

- The first transect line is determined randomly (*i.e.* starting point and direction are chosen at random). Subsequent transect lines can then be systematically arranged, parallel to the first line (Figure 2). This systematic layout of transect lines is recommended over a completely randomized layout because 1) it is easier to set up in the field; 2) it is less confusing to sample; and 3) it provides an even coverage of the Study Area, whereas a randomized design may miss certain areas.
- The final variable for the layout of a transect sampling design is the distance between transect lines. Again, this depends on the sampling intensity desired. However, too few transects will not provide a large enough sample size to allow for meaningful conclusions. On the other extreme, too many transects will result in wasted effort. The chosen design should represent a compromise between these two extremes.
- Because this survey is a presence/not detected survey there is no need to determine the width of the transect being used, as there are no area based estimates being derived. Instead the researcher should attempt to observe as many trees as possible along the entire length of the transect. The importance of the systematic transect lines is not to allow for any statistical analysis, but to ensure the entire Study Area is searched.

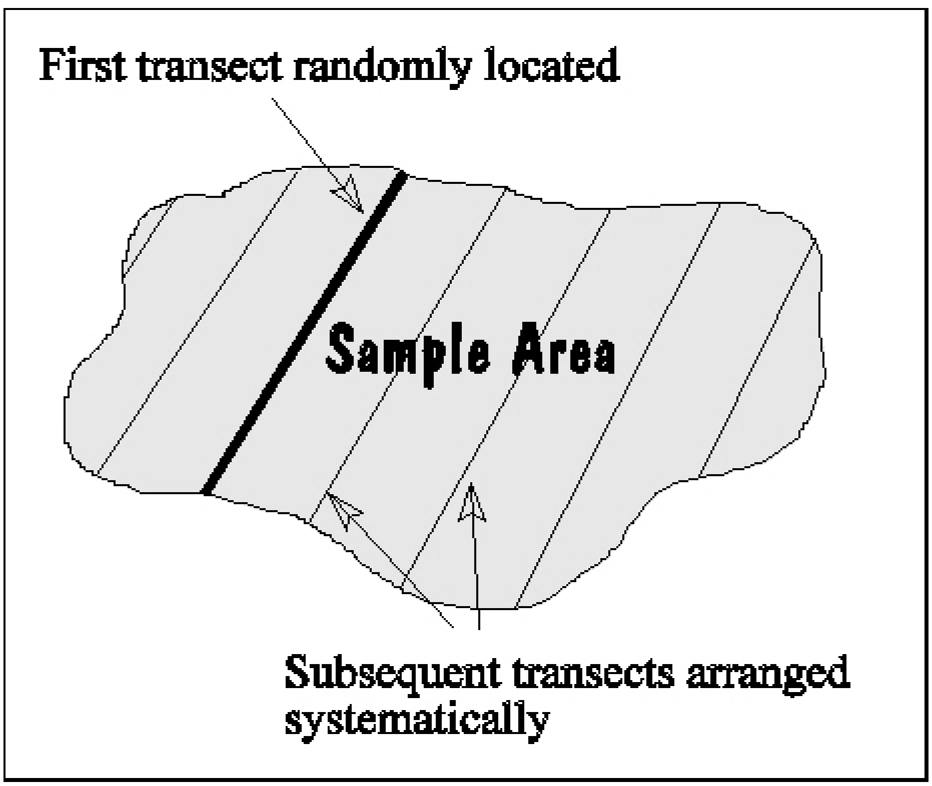

Figure 2. Appearance of a semi-systematic layout for a line transect sampling design.

Sampling effort

- The number of transects required to adequately sample the Study Area will be determined by the density of trees/understory within the area and how well researchers can observe the ground (in the case of mountain beaver and bushy-tailed woodrats) or tree tops for feeding damage (in the case of porcupines). Funds and number of researchers available will also have a bearing on the number of transects used. As the presence/not detected surveys do not require an estimate of species abundance there is no requirement for minimal number of transects for statistical purposes. It should be remembered, that to compare results between different Study Areas, the level of effort should remain constant between areas.

Sampling standards

Time of year

- *Mountain beaver and bushy-tailed woodrats* - presence/not detected surveys should be conducted during snow-free months when sign is easiest to see.
- *Porcupines* - conduct surveys in winter. As porcupines feed on trees during the winter months, the feeding damage caused is most easily identified as present winter's damage during this time period. As well, porcupine tracks are most easily seen in winter during good snow conditions. Surveys for porcupines should not begin until snow accumulations have reached the point that areas under tree cover have sufficient snow to allow tracks to be observed.

Personnel

- Two person field team.
- Personnel that are hired to conduct an inventory must be able to identify mountain beaver, woodrat and porcupine sign. Literature, field guides, and local experts can be consulted to aid in the initial identification of physical sign. This step will avoid repeatedly misidentifying sign throughout the Study Area(s).
- Personnel must also be trained to collect and record appropriate habitat information.

Equipment

- Water-proof data book and pencil
- Compass
- Flagging tape and wooden stakes (to mark the course of the transects)
- Field guides to aid in the identification of animal sign
- Camera to take photographs
- Plastic bags to collect sign for later verification

Field procedures

No Transects Used

- If the field reconnaissance identifies specific preferred habitat or habitat attributes or clumps of damaged trees (in the case of porcupines), the researchers should proceed directly to these Search units.
- To identify the location of these initial surveys a compass and hip chain should be used from a known fixed point. Ultimately, the coordinates of the Search unit will be required.
- Alternatively, a high quality GPS (NAD83) with differential correction can be used to identify the location of the habitat attribute or damaged tree clumps.
- Record all appropriate information at each Search unit.

Transects Used (also see Sampling design section)

- Lay-out transects as outlined in "Sampling design" and Figure 2, using a randomly chosen starting point and direction for the first transect. After that, transect lines may be placed systematically.
- Mark transect lines with flagging tape or wooden stakes using a compass to establish appropriate direction.
- Transects should be established by a minimum crew of two people, walking parallel transect lines. Each crew member should be equipped with a hand held two-way radio for safety.
- With the aid of a compass and a hip chain (or GPS (NAD83) if available) each person walks their transect in the pre-set direction.
- Sample along the entire length of the transect recording the distance from starting point of any sign observed.

Data analysis

- Results are commonly presented within a table indicating which animals were determined to be present within the Study Areas.

Relative Abundance

Recommended method: Physical sign survey looking for active porcupine dens and mountain beaver nest sites. No survey methods are recommended for Bushy-tailed woodrats at this time.

1.3.2 Physical Sign

As with the presence/not detected surveys, the physical sign produced by mountain beaver, bushy-tailed woodrat, and porcupine can be used to assist in conducting relative abundance surveys. Unfortunately, there is no published data relating physical sign of any of these species to animal abundance. The amount of sign produced by an individual animal can be related to many factors, including age or sex of the animal, home range size, habitat type, time of year, and weather conditions. As a result, for relative abundance surveys, physical sign alone can not be used to estimate trends in animal abundance.

Mountain beaver. For mountain beaver, physical sign can be used to find active (or probable) nest sites. Mountain beaver runways are often located within 30 m of a nest site. The nest sites are usually highly visible as the majority of vegetation within a 10 m radius of the nest site is clipped very low (L. Gyug, pers. comm.). Searching for active nest sites can give a relative estimate of the number of adult animals in an area, but there is currently no way of determining if the nest site is occupied by a female with young.

Bushy-tailed woodrat. Bushy-tailed woodrats present more of a difficulty in estimating relative abundance. Once again, all physical sign can not be used to estimate abundance, as there is no clear relationship between the amount of sign in a given area and the number of animals present. Escherich (1981) presents data indicating that it may be possible to use the number of stick houses as an index of adult woodrat abundance. Unfortunately, the relationship between numbers of stick houses and numbers of woodrats is not strong, and the ability of a researcher to distinguish between a new and old stick house is questionable. As a result, relative abundance estimates are not recommended for bushy-tailed woodrats, until such time that a stronger relationship between sign and abundance can be established.

Porcupine. Although porcupine winter dens are occasionally shared by two individuals (Roze 1989) this is relatively rare for populations studied in British Columbia (Krebs 1994; Zimmerling pers. comm.). As a result, active winter dens can be used as an index of porcupine abundance. To find active winter dens researches must rely on physical sign such as feeding damage and tracks to lead them to the den site.

Office procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals* for information on sampling design, habitat description and reporting.
- Determine the Project Area and outline it on a small to large scale map (1:250,000 – 1:20,000).
- Obtain maps for project and Study Area(s) (*e.g.,* 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps; 1:5000 air photos are generally best to evaluate habitat types).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units. Use this information in conjunction with the habitat cues provided below to delineate potential Study Areas on maps.
- Delineate one to many Study Areas within this Project Area. Study Areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area.
- If necessary, stratify each Study Area based on expected density or habitat type (*e.g.* conifer forest, deciduous forest).

Sampling design

Mountain beaver

- Mountain beavers have a strong habitat association with wet and moist areas.
- Using air photos or an appropriate scale map, wet/moist areas within the Project Area should be identified.
- The highest quality habitats are generally along small streams that are not prone to flooding and along seeps (L. Gyug pers. comm.; Beier 1989; Todd 1992). These will act as Study Areas.
- Establish transects as described in section 3.3.1 Physical Sign (under the heading Sampling Design and subheading “Systematic transects”).
- Unlike presence/not detected surveys, it is important in a relative abundance survey to keep track of the length of the transect and set the width of the transect.
- Transect width will be determined by the habitat and the ability of the researcher to see the appropriate sign at different distances within the habitat.

Porcupines

- Survey porcupines using systematic transects placed across the Study Area in question (see 3.3.1 Physical Sign, under the heading Sampling Design and subheading “Systematic transects”).

- Porcupines tend to damage trees in close proximity to their winter den sites (Speer and Dilworth 1978; Roze 1984; Griesemer *et al.* 1994) and as a result, damaged trees will appear in a clumped distribution across the landscape.
- When these clumps are encountered along a transect, the researcher can then begin to search for a fresh porcupine trail. A trail may also be encountered along a transect without being associated with a clump of damaged trees. In either case the tracks can be followed to a porcupine den.
- The number, length and width of the transects used will be determined on a survey to survey basis.

Sampling standards

Time of year

- *Mountain beaver and bushy-tailed woodrats* - relative abundance surveys should be conducted during snow-free months when sign is easiest to see.
- *Porcupines* - conduct surveys in winter. As porcupines feed on trees during the winter months, the feeding damage caused is most easily identified as present winter's damage during this time period. As well, porcupine tracks are most easily seen in winter during good snow conditions. Surveys for porcupines should not begin until snow accumulations have reached the point that areas under tree cover have sufficient snow to allow tracks to be observed.

Personnel

- Two person field team.
- Personnel that are hired to conduct an inventory must be able to identify mountain beaver, woodrat and porcupine sign.
- Personnel must also be able to identify active nest sites (for mountain beaver) and active winter den sites (for porcupines).
- Literature, field guides, and local experts can be consulted to aid in the initial identification of physical sign. This step will avoid repeatedly misidentifying sign throughout the Study Area(s).
- Personnel must also be trained to collect and record appropriate habitat information.

Equipment

- Water-proof data book and pencil
- Compass
- Flagging tape and wooden stakes (to mark the course of the transects)
- Field guides to aid in the identification of animal sign
- Camera to take photographs
- Plastic bags to collect sign for later verification

Field procedures

General procedures for mountain beaver and porcupine

- Lay-out transects as outlined in section 3.3.1 Physical Sign (under the heading Sampling Design and subheading “Systematic transects”), and Figure 2, using a randomly chosen starting point and direction for the first transect. After that, transect lines may be placed systematically.
- Mark transect lines with flagging tape or wooden stakes using a compass to establish appropriate direction.
- Transects should be established by a minimum crew of two people, walking parallel transect lines. Each crew member should be equipped with a hand held two-way radio for safety.
- With the aid of a compass and a hip chain (or GPS (NAD83) if available) each person walks his/her transect in the pre-set direction.
- Sample along the entire length of the transect.

Mountain beaver

- When runways are encountered they should be followed (usually for no more than 30 m) to find a nest site.
- A nest site is identified as an area around a burrow where the majority of the vegetation has been clipped down to a very low level (usually 10 m radius around nest site).
- When the nest site has been found, all appropriate information should be collected on the field forms.

Porcupines

- When fresh feeding damage is discovered, the area should be searched for a porcupine trail. Once found, the trail should be followed to a den site.
- If a trail is encountered along the transect without the associated damage, the trail should still be followed to a den site.
- In some cases porcupine trails may go several hundred meters before leading to a den (depending on snow conditions), or may not lead to a den at all. A decision must be made prior to the commencement of the survey as to how far each set of tracks will be followed.
- Snow conditions which result in the animal sinking 10 cm and more are optimal for tracking porcupines, as they tend to stay close to den sites, and will use the same trail repeatedly to move from den to feed trees.
- Once a den has been found its location should be recorded and the site should be marked with flagging tape. All appropriate information should be recorded on field data forms.
- The entire Study Area should be surveyed in the least number of days possible, to reduce the potential bias involved in porcupines changing den sites, (and therefor being counted more than once). Again, if the survey is conducted during a time of soft, deep snow, the likelihood of a porcupine shifting its den is greatly reduced.

Data analysis

- Relative abundance inventories for these species do not require any involved data analysis as conclusions drawn from such an inventory do not attempt to estimate actual numbers of animals present, rather simply report on observed trends. Therefore, data does not need to undergo any rigorous math, but can simply be presented as observations. For example, 10 active porcupine dens were observed in Study Area "A", whereas only five dens were observed in Study Area "B". Results may also be presented by stating that sample "A" appears to have a greater number of active dens per unit area searched.

Absolute Abundance

Recommended method: Mark-release-recapture.

1.3.3 Mark-release-recapture (MRR) - Live trapping procedure.

Any process that involves the capture, marking, and release of animals, followed by a subsequent recapture of the marked animals, is referred to as a mark-release-recapture method (MRR). Porcupines are the only animal covered in this report that, because of their visibility and inability to run fast, can be captured with or without the use of live traps. For example, a net may be used to capture porcupines on the ground, or with experience, even up a tree (John Krebs, pers. comm.). Personnel involved in trapping should be knowledgeable of standards for Wild Animal Capture and Handling (manual No. 3), another manual in the Components of British Columbia’s Biodiversity series. In addition, where telemetry is used, staff should be familiar with standards for Wildlife Radio-telemetry (manual No. 5).

Capturing mountain beavers and bushy-tailed woodrats requires the use of live traps. In general, live traps are either categorized as box traps (solid sided traps) or cage traps. The designs of all of these live traps are very similar. A spring loaded door is triggered to close by the weight of a visiting animal stepping on a treadle mechanism (usually a wire or a wire attached to a stepping plate). Several sizes of Sherman, Tomahawk, and Havahart traps are available to choose from, depending on the size of animal that an inventory targets. Many papers have been written on the effectiveness and potential biases of many of these live traps (Slade *et al.* 1993; O'Farrell *et al.* 1994). These studies can be consulted before a particular live trap is chosen.

There are numerous variations on the MRR method; however, all have common assumptions that must be met, or approximated, for subsequent data analysis and abundance estimates to be valid. These assumptions are:

1. Demographic and geographic closure (*i.e.* the sample population is not significantly altered by births, deaths, immigration or emigration during the time of sampling).
2. All members of a population must have an equal or known probability of being captured (*i.e.* any sample should be representative of the population being sampled).

Only in rare situations are both of these assumptions ever met; however, it is important that continued efforts be made to approximate them, if accurate estimates of population size are to be attained. It is possible to minimize the effects of violating assumptions by modifying the general approaches discussed below. It can be useful to review some modifications to the basic formulas in literature such as Eberhardt (1969), Cormack (1972), O'Farrell *et al*. (1977), Pollock (1982), Krebs and Boonstra (1984), Nichols *et al*. (1984), Kenneth and Anderson (1985), Wilson and Anderson (1985), and Chao (1988). However, the computer program CAPTURE integrates all of these formulae into one comprehensive package, and researchers may find it easier to consult documents which deal with the suite of models used in CAPTURE, such as Otis *et al.* (1978), White *et al.* (1982), or Rexstat and Burnham (1991). See also the introductory manual, *Species Inventory Fundamentals, No. 1.*

Office procedures

- Review the introductory manual *Species Inventory Fundamentals, No. 1* for information on sampling design, habitat description and reporting.
- Determine the Project Area and outline it on a small to large scale map (1:250,000 – 1:20,000).
- Obtain maps for project and Study Area(s) (*e.g.,* 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps; 1:5000 air photos are generally best to evaluate habitat types).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units. Use this information to delineate potential Study Areas on maps.
- Delineate one to many Study Areas within this Project Area. Study Areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area.
- If necessary, stratify each Study Area based on expected density or habitat type (*e.g.* conifer forest, deciduous forest).
- Mark transects and/or capture (trap) stations on maps according to sampling design.

Sampling design

Sampling designs for MRR will vary with the objectives of the study. Traps are often arranged systematically along long straight or meandering transect lines or in a grid. Length of transects, dimensions of grids, and distance between trap stations are variables of considerable debate. These measurements should be based on the home range used by each species of interest. For example, if an animal has a home range of one hectare it may not be necessary to have 10 traps per hectare, conversely it is likely not enough to have only one trap per two hectares. White *et al.* (1982) suggests using a trapping configuration that places four traps per average home range area. However, a problem arises when there are differences in home range sizes within a species (such may be the case between males, females, adults, and juveniles) and/or between species. The solution then becomes a compromise between highest probability of capturing the desired species of animal(s) and the most efficient use of traps.

Although many small mammal sampling designs use a transect line or grid-type layout of traps, systematic trapping is often inappropriate for sampling mountain beavers, bushy-tailed woodrats, and porcupines. Because the distribution of these animals is often patchy, a systematic trap layout would result in very low capture rates (*i.e*. many empty traps) and consequently, an inefficient use of traps. For this reason, it is recommended that traps be placed only where there is a high probability of catching the target animal. This is done by first locating areas that have evidence of the animal's presence, such as physical sign (see Section 2.1, 2.2, and 2.3), and then trapping that area. For example, when trapping bushy-tailed woodrats, Escherich (1981) notes that trapping is successful only if traps are placed in areas that have fresh urine marks, and preferably placed near the entrance to the woodrat's stick house.

If appropriate habitat is available, these animals may have a homogeneous distribution. In these high density situations, the population may be sampled by traps placed in a systematic fashion such as a grid. Density of animals is not as straight forward as dividing the number of animals by the area of the trapping grid. This is because the effective area of a trapping grid is larger than the area enclosed within its perimeter. In other words, animals that are captured along the edges of the trapping grid may also inhabit areas outside of the grid. There are a number of ways to reduce this problem of "edge effect". The most common method is to add a boundary strip around the grid's perimeter that attempts to incorporate the movements of the target species outside of the trapping grid. This boundary strip is usually based on the home range of the target animal, ideally obtained through radio-telemetry observations. Lovejoy and Black (1979) used a boundary strip of 40 m around their trapping grid when estimating mountain beaver densities. The 40 m width was chosen as it was the average distance traveled by the mountain beaver between successive captures of adults. It is important to note the potential for bias in this sort of measure, as the distance between successive trappings of an animal may differ from the distance it travels in the time interval between the captures. As well, it may not be appropriate to use a 40 m buffer in studies of other mountain beaver populations unless there is good reason to believe that home range movements are similar between the two groups.

The best way to minimize closure bias, including “edge effects”, is through proper study design. There is no *ad hoc* rigorous, statistical method which will correct for closure bias so studies must be designed to minimize this problem. For example, the grid area should be large enough that the ratio of home range: grid size is minimized, and sampling should be conducted in a short time interval. White *et al*., (1982), Bondrup-Nielsen (1983), and Otis *et al*. (1978) all discuss sample design strategies. In addition, Otis *et al*., (1978) include some methods for correction (however, these tend to require large sample sizes).

Mountain beaver

If initial observations of the Study Area indicate low numbers of mountain beaver *(*i.e., sparse sign), then live traps should be placed only where there is evidence of recent activity (Martin 1971), such as an active burrow or recent feeding damage. Trapping these sites until no new (unmarked) animals are captured will provide the best estimates of mountain beaver abundance within the Study Area. Capturing every animal in the Study Area is not required, as abundance estimates can also be provided by a number of data analyses; however, the project biologist should understand the specific assumptions and requirements of these analyses before field work begins (see the section on Data analysis below).

If initial observations of the Study Area indicate a high level of use of the area by mountain beavers (i.e., abundant sign), then a grid of live traps may be appropriate for sampling the population. Lovejoy and Black (1979) successfully sampled a population of mountain beavers using a rectangular grid (302 x 181 m) with an approximate distance of 30 m between traps. The distance of 30 m varied considerably as traps were placed at strategic locations such as burrows or runways to maximize the probability of capture. Lovejoy and Black (1979) estimated the abundance of mountain beavers within their Study Areas by using "direct enumeration" (similar to the MNA estimators: see Data analysis), however, other estimators may be more appropriate depending on the trappability of the sampled population. MNA estimators have also been the subject of some criticism (see Data analysis).

Bushy-tailed Woodrat

MRR is recommended for estimating absolute abundance of bushy-tailed woodrats. Because the bushy-tailed woodrat is usually distributed irregularly throughout a Study Area, sampling with a trapping grid would not be an efficient use of traps (Escherich 1981; Vaughan 1982; Sakai and Noon 1993). Both Escherich (1981) and Vaughan (1982) recommend that traps only be placed in areas where recent signs of activity are present. A key assumption of this approach is that the surveyor does not miss any locations in the Study Area where woodrats are found. Selectively placing traps will only introduce a minimal bias provided that the surveyor can be confident at having identified all the areas of woodrat use. Vaughn (1982) employed two traps at the entrances of any stick houses which were located. Escherich (1981) suggests placing anywhere from 4 to 25 traps (depending on the abundance of sign), in areas where the presence of a woodrat is indicated by recent urine stains. This latter approach is generally not recommended for this type of inventory, as it relies on the assumption that sign is proportional to abundance, and may result in inefficient use of traps. Instead, it is recommended that equal trapping effort is employed at each potential woodrat site. Ideally, a stratified "random" design might be utilized in which the area is pre-stratified based on potential woodrat habitat (as indicated by a preliminary, transect-based search of the Study Area to locate sign). Each stratified area is then sampled equally for a series of trap nights.

A trapping grid may be an appropriate method of sampling only if population densities are high. Vaughan (1982) suggests, under high density conditions, a one hectare grid with traps at 10 m intervals as a suitable sampling technique for woodrats. This change of approach assumes that woodrat populations become more random and less clumped at higher densities, making a grid system of trapping more appropriate. Vaughan (1982) notes that about 80 to 100 traps are the maximum number for one person to successfully check.

Choice of data analysis should depend on the calculated trappability of the woodrat population, (see the estimators discussed in the Data analysis section).

Porcupine

The use of trap transect or grids is not recommended for porcupines. Owing to the size of trap required for porcupines (adult males can be as much as 12.7 kg), researchers run a very real risk of capturing non-target species (such as bear cubs, skunks etc.) if trapping is done during spring/summer months. During the winter, porcupine movements are restricted to small areas around den sites (Speer and Dilworth 1978; Roze 1984; Griesemer *et al.* 1994) and, as a result, time and effort is wasted establishing a grid or transect system that covers large areas with no porcupine use. As for woodrats, it may be useful for biologists to conduct systematic search transects through the Study Area. A transect approach will ensure that the Study Area is searched completely for areas of activity. Traps can then be placed at the areas of activity.

To obtain an absolute abundance estimate for porcupines, it is recommended that radio transmitters be used. For this reason, absolute abundance surveys of porcupines will be limited to longer term studies. Porcupines are most easily trapped at active winter den sites. The trap entrance is placed directly in front of the den entrance so as to allow the animal no choice but to enter the trap. Once trapped, the animal is sedated and “marked (i.e., a radio-collar is placed around the neck) and the animal is released back into its den. The “recapture” is done by walking transects through the Study Area in an attempt to re-sight the animal in a tree or in an active den. When a porcupine is sighted or an active den site is found a radio receiver is used to determine if the porcupine has been previously marked. Once radio-transmitters have been placed on a significant portion of the population within a Study Area, an estimate of absolute abundance can be made, quickly and efficiently (see Data analysis). Researchers should consult (White & Garrott, 1990) and (White, 1996) for a discussion of study design and analysis strategies (program NOREMARK) for mark-resight estimation studies. Program NOREMARK has an easy to use simulation program which is useful in designing mark-resight studies.

Sampling effort

Each period of sampling is referred to as a capture (trap) session. Unless trapping is performed continuously, capture sessions should be systematic in time. For example, a capture session may consist of trapping once in the evening and again the following morning for mountain beaver or woodrats. In the case of porcupines much larger areas will generally be surveyed, and as a result it may require 2-3 days to adequately cover the entire Study Area. Monitoring intensity depends on the objectives of the study and recommendations often vary between trappers. Therefore, literature and/or experts can be consulted before a capture session schedule is chosen.

If a density estimate is required then at least four sessions should be conducted in a brief time period (to minimize violations of the assumption of closure). Many small mammal studies trap for four or five successive nights to get density estimates. The effect of trapping on animals should be considered when deciding the interval between trapping sessions; it will be less disruptive to the local population to allow for breaks in a trapping schedule. Data from this design can be used with program CAPTURE (see White et al 1982).

As an alternative, the Jolly-Seber model will allow calculation of survival estimates, as well as a population size; however, biologists should be aware that this is not a true measure of density even though it provides a good measure for comparison over time or among areas. Sampling sessions can be conducted with longer durations between trapping periods (i.e., a few sessions each month). Many analysis options exist for the Jolly-Seber model; these are discussed in *Species Inventory Fundamentals, No. 1*.

Both of the designs above can be combined to allow density and survival estimates. This design is called "Pollock's robust design" and is also discussed in *Species Inventory Fundamentals, No.1*.

For systematic sampling, one trap per capture (trap) station is usually sufficient. Within dense populations, however, 2 or 3 traps per capture station may be necessary to avoid competition for traps.

It is difficult to recommend sample sizes (numbers of observations or animals sampled) which are appropriate for every situation, as this will depend on the level of precision needed. Of course, the larger the sample size is, the more precise the abundance estimates will be. In general, sample sizes can be increased by increasing sampling effort. However, there are always limits to the amount of sampling effort that can be afforded during a study. The solution then becomes a compromise between available resources and levels of precision required to meet the objectives of the study. The simulation modules provided in CAPTURE and NOREMARK can be very helpful in determining the sampling effort needed to get adequate estimates. In addition, Pollock *et al*. (1990) provide sample size tables for the Jolly-Seber model.

Mountain beaver

Lovejoy and Black (1979) successfully estimated mountain beaver abundance by trapping one night each week. More intense trapping is likely more appropriate if the duration of the study is short. If a density estimate is desired, this will generally require a minimum of four sessions in as short a time as the species will tolerate. This will minimize violations of population closure and allow density to be calculated using the program CAPTURE. If it is desired, weekly trapping can be used to calculate survivorship and abundance using a Jolly-Seber model (see *Species Inventory Fundamentals* for more information).

Bushy-tailed woodrat

Traps should be set just before dusk and checked once between 10 p.m. and midnight, and again at closing time soon after dawn (Escherich 1981; Vaughan 1982). Three to six consecutive nights of trapping are recommended.

Porcupines

The number of days required to do the initial captures and deploy radio-transmitters will depend on the size of the Study Area and the number of transmitters available. Subsequently the number of "recapture" days required will be determined by the size of the Study Area and the number of available researchers.

Sampling standards

Time of day

- *Mountain beaver*- Night trapping is necessary because of the nocturnal habits of the mountain beaver.
- *Bushy-tailed Woodrat* - Because bushy-tailed woodrats are nocturnal, trapping should only be done at night. Owing to the sensitivity of woodrats to cold temperatures, all traps must be covered to protect the animals from rain, and bedding material such as cotton should be provided for warmth. Even when these precautions are taken, trapping should be postponed during inclement weather to avoid trap mortalities.
- *Porcupine* - Traps can be set during the day and checked the next morning. Tree branches should be used over top of the trap to block rain or snow from entering the trap. The re-sighting surveys are conducted during the day to allow researchers to observe porcupine trails or animals in the tree canopy.

Time of year

- Appropriate season of sampling is largely dependent on the species being trapped. It is, therefore, important to understand some basic biology and ecology of the species being sampled as timing of breeding seasons, and juvenile dispersal will all have an effect on trapping results.
    - *Mountain beaver*- Mountain beaver capture rates have been observed to be highest during the summer months (Lovejoy and Black 1979). Therefore, if sampling is to be completed in a short period of time (< 1 year), it is recommended that trapping be carried out May to August.
    - *Bushy-tailed Woodrat* - Literature does not suggest a season that is best suited for trapping bushy-tailed woodrats as these rodents are active year-round and do not migrate from their habitat. Therefore, it is recommended to trap during the

  spring and/or summer months when locating the animal sign and working conditions are easiest.
  - *Porcupine* - Porcupines must be sampled during winter months to allow for locating den sites and fresh trails (Smith 1982*b*).

Personnel

- Two person field team.
- Personnel hired to conduct an inventory must be able to identify mountain beaver, woodrat and porcupine sign including active mountain beaver nest sites and active porcupine winter den sites. Literature, field guides, and local experts can be consulted to aid in the initial identification of physical sign. This step will avoid repeatedly misidentifying sign throughout the study.
- Personnel must be trained to collect and record appropriate habitat information.
- Personnel must be trained in the appropriate method for handling live animals and must be able to identify the sex of the animal, breeding condition and ear tag the animal if required.
- Personnel working on porcupines should be trained in: techniques for capturing the animals in tree canopy; administrating an anesthetic (the immobilization of wild animals should only be performed by trained personnel who have successfully completed a Ministry Chemical Immobilization Training Course, see Ministry Chemical Immobilization of Wildlife Policy); and in techniques for fitting a radio-transmitter on porcupines.

Equipment

- Water proof data book and pencil(s)
- Head-lamp for trapping at night
- Flagging tape and wooden stakes (to mark trap location)
- Cage traps:
  - Mountain beaver: 15 x 15 x 61 cm cage traps.
  - Bushy-tailed woodrat: Havahart or Tomahawk live traps (Although Vaughan (1982) suggests that Sherman live traps be used, Escherich (1981) noted Sherman traps to cause serious injury to bushy-tailed woodrats).
  - Porcupine: Cage trap (40 cm x 40 cm x 100 cm) if animal is inaccessible; otherwise hand trap with fish landing net.
- Large shingles, square pieces of plywood, or tar paper for covering traps (mountain beaver and bushy-tailed woodrats).
- Coarse raw cotton for bedding
- Bait: apples for mountain beaver and porcupine and rolled oats for bushy-tailed woodrat
- Fish landing net for capturing porcupine
- Handling cage or cone-shaped nylon fishnetting bag for handling animals
- Leather gloves for handling animals
- Numbered metal (fingerling) ear tags and ear tagging pliers or colour dye or non-toxic paint.
- Spring balance (if required by study objectives)
- Anesthetic (see Sweitzer and Berger 1992; Hale *et al.* 1994; Krebs 1994)

Traps are available from:

Sherman Traps	**Tomahawk Live Traps**	**Havahart Live Traps**
H. B. Sherman Traps, Inc. Tallahassee, Florida	Tomahawk Live Trap Co. Tomahawk, Wisconsin	Ekco Canada Niagara Falls, Ontario
Tel. (904) 562-5566	Tel. (715) 453-3550	Tel. (905) 357-3440, Fax (905) 357-3445

Field procedures

Mountain beavers and Bushy-tailed woodrats

- Lay out grids, arrays, and/or capture trap stations within each Study Area and mark trap stations with flagging tape and wooden stakes.
- Place traps. Suitable traps for each species are itemized in the above Equipment section.
    - For a systematic sampling design, place live traps within a 2 m radius of a given capture station. Within that 2 m radius, place traps within a strategic location, such as along an active runway or near a burrow, to maximize the probability of capture.
    - For a non-systematic sampling design (*i.e*. traps placed near animal sign), trap placement is not restricted.
    - Place traps under natural cover (a log, thick brush, etc.) or cover with a square (30 x 30 cm) piece of plywood or shingle (for smaller box traps) or by roofing paper folded lengthwise over the top and two sides of larger cage traps. This cover shades the animals from direct sunlight and shelters them from rain, thereby reducing animal stress and possible trap moralities.
    - Traps should be placed in a stable manner to prevent an animal from being scared away from a trap that rocks or wobbles when it is stepped in.
- Bait traps. Bait has two purposes in live trapping: 1) it sustains the animal while captive in the trap; and 2) may serve as an attractant for the animals, thereby increasing the probability of capture. Types of bait used will largely depend on the species being trapped (suggested bait: apples for mountain beaver and rolled oats for bushy-tailed woodrat).
- Set traps. In most cases, setting traps simply implies baiting it with the appropriate bait (and bedding, if required) and adjusting the trap so that it will capture a visiting animal. These adjustments usually involve manually setting off the trap a few times to insure that the trap door closes properly upon tripping the treadle mechanism.
    - *Important Note*- A prebait is a pre-sampling period in which doors of baited traps are locked open to allow the animal in the trap without being captured. A prebait is highly recommended to allow the animals to habituate to the presence of the traps within their environment. This will significantly increase the probability of trapping otherwise hard to catch animals.
- Check traps according to sampling design and effort.
- Restrain animals. The method of handling animals primarily depends on the species of animal trapped. The method of choice should always attempt to minimize the animal's level of stress. Standards for restraint of mammals are outlined in Wild Animal Capture and Handling manual No. 3, also part of this series. Below are some examples of

handling methods used by various experts. Literature and/or experts can be consulted for a more detailed description of handling.

- ***Mountain beavers****:* Transfer the captured animal from the live trap to a handling cage or bag (Lovejoy and Black 1979). Lightly anaesthetizing the animal is also recommended by Martin (1971).
- ***Bushy-tailed Woodrats:*** Escherich (1981) suggests that this animal be transferred from the live trap to a handling bag constructed of 8 mm nylon fishnetting (Escherich 1981). Once in the bag the animal may be handled with a gloved hand.

- Collect data. Once the animal has been restrained, in the hand or in a holding bag, the following information is commonly recorded:
  1. Species
  2. Identification marking (ear tag number, or colour dye marks)
  3. Point of capture: Capture station or reference to a sketched map
  4. Sex. Rodents are generally straight forward to sex as sexual dimorphism exists, however, juveniles may still be difficult to discern
  5. Weight. Pesola® spring scales are recommended
  6. Reproductive condition (if required). Male rodents - by palpation of testes to determine whether scrotal or abdominal. Female rodents - by observing the condition of mammaries (*i.e*. lactating or not).
- Mark all animals.
  - There are three common marking techniques applied to animals during MRR sampling; numbered ear tags, pelage dyes and toe clipping (not recommended). The most common form of marking animals is ear tagging. Numbered metal ear tags ("fingerling tags") should be placed low in the ear (where the cartilage is the thickest) and within the inner edge of the ear to reduce the risk of the tag being ripped out (Call 1986). Placing one tag in each ear also reduces the risk of losing the identity of an individual by tag loss.
  - In cases where the survey is short term (5 days or less) or animals are too small to allow for ear tagging, pelage dyes can be used. Numerous colours of hair dye can be used or alternatively, a non-toxic paint. The dyes, or paint are used to make a semi-permanent mark on the pelage of the animals. In most MRR surveys, identification of individual animals is not required; however, if individuals must be identified, then unique patterns and colour combinations of dots, crosses or lines allow for a large number of animals to be given unique, individual marks.
  - Although toe clipping has been used by a number of researchers (Day *et al.* 1980; Davis 1982a) this method is not recommended as it conflicts with the standards of some animal care agencies and may significantly reduce the survival of the marked animals (Pavone and Boonstra 1985).
- Release animals at point of capture.

Field Procedures Porcupines

- Establish systematic transects for porcupines as described for Physical Sign surveys in the previous "Relative Abundance" section.

- Walk the transects looking for sign as described in the previous “Relative Abundance” section.
- When a trail is found it should be followed. Following a fresh trail will lead to a porcupine on the ground, in a tree or in a winter den.
- If the porcupine is in a den: set a large cage trap baited with apples at the den entrance. A corral built of snow and tree branches should be used to ensure the porcupine is forced to walk into the trap. Once in the trap, transfer the porcupine to a large landing net for handling.
- If the animal is found on the ground: capture using a large landing net. This process must be quick, as the animal will instinctively head for a tree and will quickly climb out of reach.
- If the porcupine is in a tree: the tree can be climbed (with a climbing belt) and the porcupine scooped into the landing net and lowered down to the ground. Getting a porcupine into a net while in a tree can be very challenging and this method may not be suitable for people unfamiliar with this technique. Tree capture should only be attempted by experienced researchers who are comfortable with the procedure or professional tree climbers who have been thoroughly briefed as to how to properly handle a netted porcupine to minimize danger to both themselves and the captured animal. Standards for restraint of mammals are outlined in Wild Animal Capture and Handling manual No. 3, also part of this series.
- Once the porcupine is in the net it should be weighed (with the net) and the appropriate amount of anesthetic determined. The anesthetic is delivered with a hypodermic needle in the base of the tail. Immobilization and collaring should not be attempted by any person without both training and practical experience. (personnel must have successfully completed a Ministry Chemical Immobilization Training Course, see Ministry Chemical Immobilization of Wildlife Policy).
- Once the animal is unconscious, remove it from the net and place it on a piece of leather or cloth to insulate it from the cold ground.
- Quills around the neck should be clipped with scissors to allow for the collar. Clipping the quills prevents the collar from pushing a quill into the skin of the animal. Fit the radio-collar.
- Collect data: Once the animal has been collared, the following information is commonly recorded:
    1. Species
    2. Identification marking (ear tag number)
    3. Point of capture. Capture (trap) station or reference to a sketched map
    4. Sex. With porcupines it is important to realize that both males and females have prominent nipples so this characteristics can not be used to determine sex
    5. Weight. Pesola® spring scales are recommended (must be able to weigh to 15 kg minimum)
    6. Reproductive condition is not recorded, as the survey occurs during winter months.
- All animals should be marked with a numbered metal ear tag, in case the radio transmitter fails or is lost from the animal.

- Release animals at point of capture on a bed of branches to insulate the animal from the ground.
- Researchers should watch the animal until it has recovered to the point that it is able to mount a defensive posture (quills erect) or until it crawls back into its den.
- After the initial “marking” period, the subsequent “recapture” is achieved by walking the systematic transects as described previously. Any porcupine encountered (in tree, on ground or in den) is then counted as a capture (although no physical capture occurs). Each individual is checked with a radio receiver to determine if it has been previously radio-collared. If the animal has a radio-collar it is marked, if it has no collar it is counted as unmarked. An active den can be counted as a capture, as the radio-receiver can be used to determine if the animal in the den has a collar or not.
- As the animal is not physically handled during the “recapture,” data collected is limited to habitat information.

Data analysis

The project biologist should be familiar with the different methods of data analysis for mark-recapture inventories before data collection begins. Different assumptions and requirements of the various models will have great bearing on sample design, effort and overall approach.

Below is a cursory discussion of mark-recapture models. This is included to provide biologists with an overview; however, a greater depth of knowledge will be required to actually carry out a mark-recapture inventory. Prior to commencing, it will be necessary to consult *Species Inventory Fundamentals No. 1* as this manual provides descriptions of many techniques which are generic to species inventory. In addition, the following is a short list of some useful texts and articles. For complete citations see Literature Cited.

1. White *et al.* 1982. In some opinions, this is by far the most readable reference on mark-recapture that is available. Available at:

   http://www.cnr.colostate.edu/~gwhite/software.html
2. Buckland *et al.* 1993. Good text for distance and transect sampling.
3. Krebs 1989, (also 1998, 2nd Edition). Good all round discussion of study design, but Chapter 2, Estimating abundance: Mark-and-Recapture techniques, is especially appropriate).
4. Pollock *et al.* 1990. A good discussion of the Jolly-Seber model.
5. White and Garrot 1990. A good discussion of study design for radio-telemetry estimation studies.
6. White 1996. A good discussion of mark-resight estimation procedure.
7. Schemnitz 1980. *Wildlife management techniques manual* (especially chapter 14 - Estimating the numbers of wildlife populations. pp 221-246).

There are numerous ways of analyzing data from a MRR program. The level of confidence placed in any estimator is largely dependent upon sample size, sample effort and how well the assumptions of the analysis methods are met in the field. Some common methods of analyses found in the literature are summarized below to provide some background information. Many sophisticated and robust methods of analyzing MRR data are available as part of the programs CAPTURE, JOLLY and MARK; all of these are discussed in *Species Inventory Fundamentals*.

Minimum-Number-Alive Estimator (MNA)

One of the easiest ways of estimating the abundance of a population from a mark-release-recapture (MRR) program is called the minimum number alive method (MNA). MNA (also called the calendar count or enumeration) is an estimate based on the sum of all individuals known to be alive during a particular capture (trapping) session. An individual is known to be alive during a given capture session if it was captured during that session, or if it was captured before and after that capture session. For example, if an individual is captured during capture session #1 and #3, it can be accurately stated that it was missed (but alive) during session #2.

Although the MNA method is simple to use, this estimator has been criticized as being negatively biased in most situations. For this reason, in a summary, Ritchie and Sullivan (1989) suggest that the MNA estimate should only be used when the trappability of animals is >70%. Several articles have been written on the use of the MNA estimator (Hilborn *et al.* 1976; Jolly and Dickson 1983; Nichols and Pollock 1983; Boonstra 1985; Efford 1992; Hilborn and Krebs 1992). Most of these papers recommend the use of the Jolly-Seber estimator over MNA if trappability is low or unknown.

Estimation by Asymptotic Capture

Population abundance can be estimated by intensively trapping and marking a population until no new (unmarked) individuals are captured. This method is essentially a modified (i.e., non-lethal) version of kill trapping where animals are removed until no animals remain.

Ratio estimators

The Lincoln, Petersen, and Schnabel estimators are based on the ratio of marked to unmarked individuals within a population. These estimators assume that the population is “closed” to immigration and emigration. The formulas are based on the assumption that the population size is related to the number of marked and released animals in the same way that the total caught at a subsequent time is related to the number recaptured (Davis and Winstead 1980). White *et al.* (1982) offer excellent discussion of closed models which many be calculated using the program CAPTURE.

The Petersen estimate is the most basic MRR method. It is based on two sample periods only (i.e., one period of marking animals, followed by a single period of recapture). It is described using the following formulas:

$$\frac{N}{M} = \frac{C}{R} \tag{1}$$

therefore:

$$N = \frac{CM}{R} \tag{2}$$

where:

N = Population Estimate

M = Number of marked and released animals

C = Total number of animals captured

R = Number of marked animals that were recaptured

Numerous variations on the Petersen Estimate have been developed. The Petersen Estimate is biased in that it tends to overestimate the actual population, especially if the sample is small. In response to this bias, Seber (1982) offers a variation on Petersen's formula that is less biased, and nearly unbiased if there are at least seven recaptures of marked animals. Another variation, the Schnabel estimate was developed to allow investigators to analyze data from multiple (>2) marking sessions.

The Jolly-Seber Estimator

Like the Lincoln, Petersen, and Schnabel estimators (above), the Jolly-Seber estimator is also based on the ratio of marked to unmarked individuals within a population. However, the Jolly-Seber estimate differs from others in that it recognizes, and attempts to incorporate, the fact that biological populations are generally not closed to immigration or emigration. This "open" model will not provide a true estimate of density, but rather of abundance, as the population is not defined in terms of area. This estimator requires that at least three sampling periods be carried out in order to calculate certain variables. Pollock *et al.* provide good discussion of Jolly-Seber models, and the program JOLLY is very useful for simulating MRR or analyzing data.

The formula for the Jolly-Seber estimate of population size is given below.

$$N_t = \frac{M_t}{\alpha_t} \qquad (3)$$

where:

N_t = Population estimate just before sample t

t = Sample period (1,2,3,4,5,......t th sample)

α_t = proportion of animals marked

$$\alpha_t = \frac{m_t + 1}{n_t + 1} \qquad (4)$$

m_t = Number of marked animals that were recaptured during sample t

n_t = Total number of animals captured during sample t

M_t = Estimated number of marked animals just before sample t

$$M_t = \frac{(s_t + 1)Z_t}{R_t + 1} + m_t \qquad (5)$$

s_t = Number of animals released

s_t = (n_t - accidental deaths)

R_t = Number of animals released during sample t, or s_t that were recaptured during a later sampling period

Z_t = Number of animals that were not captured during sample t, but were captured before and after sample t

Glossary

ABSOLUTE ABUNDANCE: The total number of organisms in an area. Usually reported as absolute density: the number of organisms per unit area or volume.

ACCURACY: A measure of how close a measurement is to the true value.

ARBOREAL: Adapted for living within trees.

ASYMPTOTE: Mathematically, an asymptote is a value that is approached, but never quite reached, by observed values. Graphically, an asymptote appears as a "leveling off" of observations.

BIODIVERSITY: Jargon for biological diversity: "the variety of life forms, the ecological roles they perform, and the genetic diversity they contain" (Wilcox, B.A. 1984 cited in Murphy, D.D. 1988. Challenges to biological diversity in urban areas. Pages 71 - 76 *in* Wilson, E.O. and F.M. Peter, Eds. 1988. Biodiversity. National Academy Press, Washington, DC. 519 pp.).

BLUE LIST: Taxa listed as BLUE are sensitive or vulnerable; indigenous (native) species that are not immediately threatened but are particularly at risk for reasons including low or declining numbers, a restricted distribution, or occurrence at the fringe of their global range. Population viability is a concern as shown by significant current or predicted downward trends in abundance or habitat suitability.

CACHE: A storage, usually of food for the winter months.

CARRION: Dead and decaying flesh.

CBCB (Components of B.C.'s Biodiversity) Manuals: Wildlife species inventory manuals that have been/are under development for approximately 36 different taxonomic groups in British Columbia; in addition, six supporting manuals.

CENSUS: A census is a count of a given species for a given area. Because an actual count of wild animals is rarely possible, some sort of sampling design is often employed in order to estimate a census.

CONSPECIFIC: Conspecifics are animals that belong to the same species.

COPROPHAGY: Coprophagy is the reingesting of soft feces to capture nutrients that would otherwise be wasted.

CREPUSCULAR: Active at twilight

DESIGN COMPONENTS: Georeferenced units which are used as the basis for sampling, and may include geometric units, such as transects, quadrats or points, as well as ecological units, such as caves or colonies.

DIURNAL: Active during the daytime

EWG (Elements Working Group): A group of individuals that are part of the Terrestrial Ecosystems Task Force (one of seven under the auspices of RIC) which is specifically concerned with inventory of the province's wildlife species. The EWG is mandated to provide standard inventory methods to deliver reliable, comparable data on the living "elements" of BC's ecosystems. To meet this objective, the EWG is developing the CBCB series, a suite of manuals containing standard methods for wildlife inventory that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species populations.

FOSSORIAL: Adapted for living below the ground.

GESTATION PERIOD: Time required for the development of a healthy fetus (i.e. time period from fertilization to birth).

GREGARIOUS: Living in communities; fond of company.

HERBIVORE: Animal adapted for eating plant matter only.

HIBERNATION: A period of dormancy (lowering of metabolic rate so as to reduce energetic demands for survival) assumed by some animals during periods of unfavourable climatic conditions.

INVENTORY: The process of gathering field data on wildlife distribution, numbers and/or composition. This includes traditional wildlife range determination and habitat association inventories. It also encompasses population monitoring which is the process of detecting a demographic (e.g. growth rate, recruitment and mortality rates) or distribution changes in a population from repeated inventories and relating these changes to either natural processes (e.g. winter severity, predation) or human-related activities (e.g. animal harvesting, mining, forestry, hydro-development, urban development, etc.). Population monitoring may include the development and use of population models that integrate existing demographic information (including harvest) on a species. Within the species manuals, inventory also includes, species statusing which is the process of compiling general (overview) information on the historical and current abundance and distribution of a species, its habitat requirements, rate of population change, and limiting factors. Species statusing enables prioritization of animal inventories and population monitoring. All of these activities are included under the term inventory.

MARK-RECAPTURE METHODS: Methods used for estimating abundance that involve capturing, marking, releasing, and then recapturing again one or more times.

MONITOR: To follow a population (usually numbers of individuals) through time.

NOCTURNAL: Active at night

OBSERVATION: The detection of a species or sign of a species during an inventory survey. Observations are collected on visits to a design component on a specific date at a specific time. Each observation must be georeferenced, either in itself or simply by association with a specific, georeferenced design component. Each observation will also include numerous types of information, such as species, sex, age class, activity, and morphometric information.

OMNIVORE: Animal that consumes both plant and animal matter.

POPULATION: A group of organisms of the same species occupying a particular space at a particular time.

PRECISION: A measurement of how close repeated measures are to one another.

PRESENCE/NOT DETECTED (POSSIBLE): A survey intensity that verifies that a species is present in an area or states that it was not detected (thus not likely to be in the area, but still a possibility).

PROJECT AREA: An area, usually politically or economically determined, for which an inventory project is initiated. A project boundary may be shared by multiple types of resource and/or species inventory. Sampling for species generally takes place within smaller, representative Study Areas so that results can be extrapolated to the entire Project Area.

PROJECT: A species inventory project is the inventory of one or more species over one or more years. It has a georeferenced boundary location, to which other data, such as a project team, funding source, and start/end date are linked. Each project may also be composed of a number of surveys.

RANDOM SAMPLE: A sample that has been selected by a random process, generally by reference to a table of random numbers.

RED LIST: Taxa listed as RED are candidates for designation as Endangered or Threatened. Endangered species are any indigenous (native) species threatened with imminent extinction or extirpation throughout all or a significant portion of their range in British Columbia. Threatened species are any indigenous taxa that are likely to become endangered in British Columbia, if factors affecting their vulnerability are not reversed.

RELATIVE ABUNDANCE: The number of organisms at one location or time relative to the number of organisms at another location or time. Generally reported as an index of abundance.

RIC (Resources Inventory Committee): RIC was established in 1991, with the primary task of establishing data collection standards for effective land management. This process involves evaluating data collection methods at different levels of detail and making recommendations for standardized protocols based on cost-effectiveness, co-operative data collection, broad application of results and long term relevance. RIC is comprised of seven task forces: Terrestrial, Aquatic, Coastal/Marine, Land Use, Atmospheric, Earth Sciences, and Cultural. Each task force consists of representatives from various ministries and agencies of the Federal and BC governments and First Nations. The objective of RIC is to develop a common set of standards and procedures for the provincial resources inventories. [See http://www.for.gov.bc.ca/ric/]

SEARCH UNITS: Specific portions of the Study Area on which search effort was focused e.g. seepage areas.

SPI: Abbreviation for ‘Species Inventory’; generally used in reference to the Species Inventory Datasystem and its components.

STRATIFICATION: The separation of a sample population into non-overlapping groups based on a habitat or population characteristic that can be divided into multiple levels. Groups are homogeneous within, but distinct from, other strata.

STUDY AREA: A discrete area within a project boundary in which sampling actually takes place. Study areas should be delineated to logically group samples together, generally based on habitat or population stratification and/or logistical concerns.

SURVEY: The application of one RIC method to one taxonomic group for one season.

SYSTEMATIC SAMPLE: A sample obtained by randomly selecting a point to start, and then repeating sampling at a set distance or time thereafter.

TERRESTRIAL ECOSYSTEMS TASK FORCE: One of the seven tasks forces under the auspices of the Resources Inventory Committee (RIC). Their goal is to develop a set of standards for inventory for the entire range of terrestrial species and ecosystems in British Columbia.

YELLOW-LIST: Includes any native species which is not red- or blue-listed.

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